

Transportation Energy Use

Oil is expected to remain the primary fuel source for transportation throughout the world, and transportation fuels are projected to account for almost 57 percent of total world oil consumption by 2020.

Trends and Projections

Energy demand for transportation is projected to grow by 2.5 percent per year from 1999 to 2020, a higher pace than that forecast for energy demand as a whole (Table 24 and Figure 80). As a result, the transportation sector's share of total world energy consumption is projected to rise slightly, to just over 21 percent by 2020. Economic expansion and higher incomes are expected to increase the use of energy for transportation, as businesses and individuals demand greater mobility for themselves and their products. At the regional level, "transportation energy intensity"—defined here as the amount of energy used in the transportation sector per unit of gross domestic product (GDP)—is expected to decline in all regions over the forecast period (Figure 81), holding down some of the potential growth in transportation energy use. For the world as a whole, transportation energy demand per unit of GDP is expected to fall by 0.7 percent per year from 1999 to 2020.

The high oil prices and tight markets that characterized the world energy industry in 2000 were reversed in 2001. Even before the terrorist attacks of September 11, 2001, slowing economic growth and switching back to natural gas were moderating growth in oil demand [1]. The 2001

growth in energy demand for the transportation sector is likely to be the lowest in several years. From 1995 to 1999, energy consumption for transportation increased at an annual average rate of about 1 million barrels per day. In 2001, however, jet fuel and gasoline, the mainstays of the transport sector, both showed demand weakness that was exacerbated after September 11. World oil demand projections for 2001 were lowered to an increase of 0.4 million barrels per day in EIA's November *Short-Term Energy Outlook*, from 1.0 million barrels per day in the forecast before the attacks [2].

Jet fuel is expected to remain the fastest growing fuel for transportation, although the near-term outlook was severely weakened by the September 11 attacks. The demand for air travel fell significantly as a general reluctance to fly caused many travelers to postpone or cancel their travel plans. In the aftermath of the attacks, EIA estimated that jet fuel demand probably fell by about 10 percent outside the United States and as much as twice that within the United States. Jet fuel demand in the United States is estimated to have fallen by 11 percent in the second half of 2001 from year-earlier levels. A 1-percent increase is projected for the United States in 2002, and global jet fuel demand is expected to be down by roughly 5 percent [3].

Table 24. Transportation Energy Use by Region, 1990-2020

Region	Transportation Energy Consumption (Million Barrels Oil Equivalent per Day)				Average Annual Percent Change	
	1990	1999	2010	2020	1990-1999	1999-2020
Industrialized	21	25	31	36	1.9	1.7
North America	13	15	20	24	1.8	2.1
Western Europe	6	8	9	9	1.8	1.1
Industrialized Asia	2	3	3	3	3.0	1.1
EE/FSU	4	2	3	4	-5.4	2.9
Developing	8	11	17	25	4.4	3.8
Asia	3	6	10	16	6.4	4.9
Middle East	1	2	2	2	2.6	0.6
Africa	1	1	2	2	1.9	2.9
Central and South America . . .	2	2	3	5	3.2	3.1
Total World	33	39	52	65	2.0	2.5

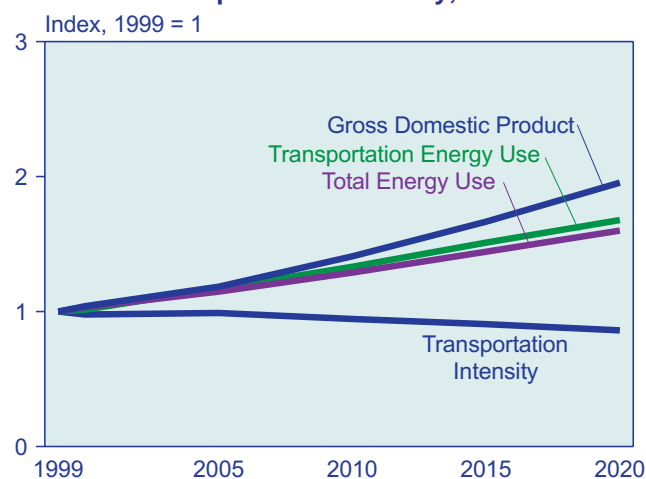
Note: Data include nonpetroleum sources of energy used in the transportation sector.

Sources: **History:** Derived from Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

The airline industry, which was showing signs of weakness before the attacks, has also been severely affected. In response to the drop in air travel, airlines in the United States have cut flights and announced job losses exceeding 100,000 [4]. The U.S. Congress allocated \$15 billion to sustain the airlines as executives warned of imminent bankruptcies in the industry [5]. Airline troubles extended beyond the U.S. border due to the steep decline in international air travel and soaring insurance rates. Financial support was announced for several airlines, with some declared bankrupt and closed down or sold. French airplane manufacturer Airbus announced that it was freezing its production expansion plans at current levels, although it will still proceed with the development of its A380 super jumbo aircraft [6]. Airbus expects the number of the very large aircraft in service to reach 1,235 by 2019, more than half of which are expected to operate from only 10 airports [7].

Airport development continued in 2001, and growth in air travel is expected to remain robust in the long term; but finding space for new airports remains a problem. The new Incheon International Airport near Seoul, South Korea, is built on a man-made land bridge between two islands, following the example set by Japan's Osaka International Airport, which is built on a man-made island [8]. Japan is considering a new 1.6-mile runway for Tokyo's Haneda Airport, elevated 66 feet above sea level in Tokyo Bay in order not to interfere with maritime traffic [9]. Two locations are being considered for a new airport for Mexico City, one 22 miles from the city and the other 53 miles to the north [10].

Figure 80. Changes in World Gross Domestic Product, Energy Demand, Transportation Energy Use, and Transportation Intensity, 1999-2020



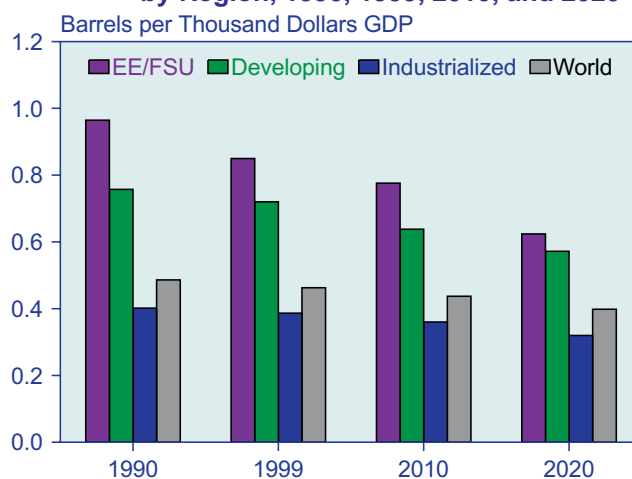
Sources: **1999:** Derived from Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **2000-2020:** EIA, World Energy Projection System (2002).

After jet fuel, diesel fuel is projected to show the strongest growth, further increasing demand for the middle of the barrel at the expense of gasoline and heavy fuel oil. Europe and South Korea currently have tax regimes that favor diesel over gasoline. Strong growth in diesel fuel is also projected for China and India. Some believe that the United States will have to move toward diesel if fuel efficiency standards are raised.

World vehicle ownership is projected to increase from 122 vehicles per thousand people in 1999 to 144 vehicles per thousand in 2020. Growth in per capita vehicle ownership is expected to slow in industrialized countries as saturation levels begin to be reached. In most of the developing nations, growth in vehicle ownership is expected to continue at a rapid pace. More rapid demand growth in the developing countries is a trend that is expected to occur throughout the transportation sector (Figure 82), and more than one-half of the increase in the world's transportation energy use is projected to take place in developing countries. With their higher economic growth rates and higher energy intensities, the developing countries' share of transportation energy demand is expected to rise from 29 percent in 1999 to 38 percent in 2020.

Future transportation demand trends will also be influenced by government policies directed at reducing emissions and congestion while promoting alternative fuels, new vehicle technologies, and mass transit. Such policies are aimed at vehicle efficiencies, the cost and quality of fuels consumed, the composition of fuels used for transportation, infrastructure development, and the research and development of new technologies.

Figure 81. World Transportation Energy Intensity by Region, 1990, 1999, 2010, and 2020



Sources: **1990 and 1999:** Derived from Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **2010 and 2020:** EIA, World Energy Projection System (2002).

Tensions among the goals of achieving economic growth, environmental improvement, and energy security are especially evident in the transportation sector. The ability to develop sustainable mobility and meet those three goals has been the focus of numerous studies and policy development activities. Over the past year, several governmental bodies around the world have produced or are in the process of developing transportation sector policies that could have considerable impact on the shape of future transportation trends, as discussed in the regional activity section below.

Sustainable mobility has become a catch phrase, defined as “the ability to meet the needs of society to move freely, gain access, communicate, trade, and establish relationships without sacrificing other essential human or ecological values today or in the future” [11]. It is being driven by the desire to improve urban air quality, reduce greenhouse gas emissions, and lower dependence on oil imports. Some have argued that it is through efficiency gains that sustainability is possible [12]. The focus is often on technological advances that will result in vehicles with few if any harmful emissions and significantly lower fossil fuel consumption. In the long term, sustainability is seen by many as a movement completely away from fossil fuels to a hydrogen-based energy system [13].

Alternatives to oil are being promoted to move toward sustainability goals in the near term. Compressed natural gas (CNG) and liquefied petroleum gases (LPG)²⁵ continue to be promoted in many countries. Thailand and Malaysia are experimenting with the development

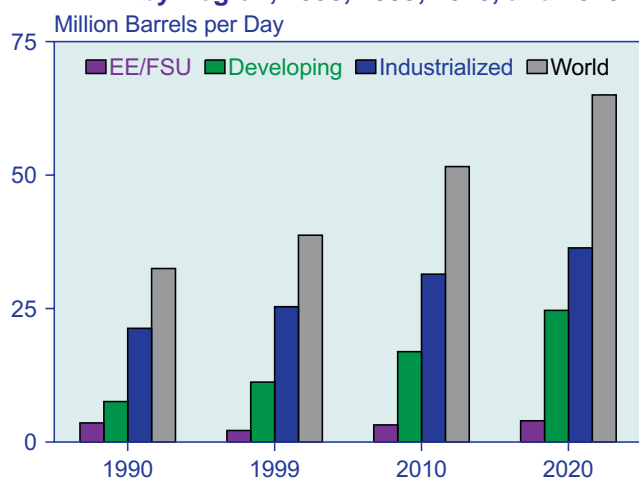
of fuel using palm and coconut oils, and Brazil, Mexico and Thailand are promoting ethanol from sugar cane. Although many countries are promoting alternatives to petroleum, their market share is expected to remain relatively small throughout the forecast, because market penetration is slow and the development of the infrastructure needed to support new energy sources remains daunting.

The share of transportation energy use made up by oil consumption is not expected to drop significantly in the *IEO2002* forecast, but oil’s dominance may begin to be challenged by advancing technologies. Several technologies designed to improve the efficiency of internal combustion engines are already entering the market, including continuously variable transmission, which provides an infinite set of gear ratios, and displacement-on-demand, which turns cylinders on or off according to driving conditions. Gas-to-liquids (GTL) technology may be able to provide liquid fuels from a non-oil source without requiring major changes in fuel distribution infrastructure. Hybrid and fuel cell vehicles, however, are getting most of the attention as technologies that could significantly alter future transportation oil demand.

Most of the world’s major automobile companies have plans to introduce some form of hybrid and/or fuel cell vehicle in the next decade. Honda and Toyota already have hybrid cars on the market. General Motors is developing a diesel hybrid bus, to be followed by hybrid pickups and sport utility vehicles, and expects to have gasoline-powered fuel cell vehicles developed by the end of the decade that will cut emissions to trace amounts and increase the fuel efficiency of today’s vehicles by 50 percent [14]. DaimlerChrysler, Honda, and Toyota have also stated that they plan to have fuel cell vehicles developed by 2004 [15]. Honda Motor Company began road tests in July 2001 on a new fuel cell vehicle that runs on compressed hydrogen. The vehicle achieved driving performance closer to that of traditional vehicles, showing improvement over previous versions with regard to speed, acceleration, and cruising distance [16].

Significant technological, economic, and fueling infrastructure barriers remain for both hybrid and fuel cell vehicles. For example, the U.S. National Research Council has indicated that successful commercial application of fuel cells for passenger vehicles is at least 10 to 15 years away [17]. General Motors has also indicated that although fuel cell vehicles will begin to appear on streets in the next few years, they will be demonstration projects at least through the middle of the decade. Even if the projected cost reductions for fuel cell vehicles are

Figure 82. World Transportation Energy Use by Region, 1990, 1999, 2010, and 2020



Sources: **1990 and 1999:** Derived from Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **2010 and 2020:** EIA, *World Energy Projection System* (2002).

²⁵ Although LPG is an oil product, a large proportion is derived from wet natural gas streams. Because reserves of natural gas are widely dispersed, LPG use does not evoke the same security concerns as other petroleum products.

achieved, the economics still may favor traditional gasoline engines in countries where gasoline prices are relatively low [18].

One of the biggest obstacles to the penetration of fuel cell vehicles is the infrastructure needed to make the fuel widely available. For gasoline fuel cells the infrastructure is already in place, but infrastructure would have to be developed for methanol or hydrogen. In the United States a task force has been formed to draft a plan for the development of infrastructure for hydrogen-based vehicles and power plants. So far, it appears that the infrastructure needed to produce, transport, store, and distribute hydrogen will be very expensive to develop [19]. It may also be possible, however, to develop a dual-fuel engine that would run on gasoline as well, which would allow the infrastructure to be introduced gradually. BMW has unveiled a prototype car with a hydrogen-powered engine [20].

Although the existing distribution system favors gasoline fuel cell vehicles, hybrid vehicles may be able to achieve levels of fuel efficiency and emissions reductions comparable to those of gasoline fuel cell vehicles at a much lower cost. If so, it is possible that gasoline fuel cell cars could lose out to hybrids [21].

The movement toward advanced technologies will continue to put pressure on refiners to produce the cleaner fuels needed for fuel efficiency gains and emission reductions. Essentially sulfur-free gasoline and diesel, containing 10 parts per million (ppm) sulfur or less, will be needed for the most promising advanced engine and emission control systems. Even lower sulfur levels will be needed for fuel cell vehicles. In addition, gasoline with more tightly controlled distillation properties may be needed, as well as lower aromatics in both gasoline and diesel fuel [22]. Although refiners have resisted improving some fuel characteristics to the extent that automakers say they need, the movement toward cleaner fuels is a worldwide trend that is likely to continue.

Regional Activity

North America

North America accounted for 39 percent of the world's fuel use for transportation and 49 percent of the world's gasoline consumption in 1999. The largest regional increase in gasoline demand in the forecast period is projected for North America (Figure 83), where gasoline currently captures 62 percent of the transportation fuels market.

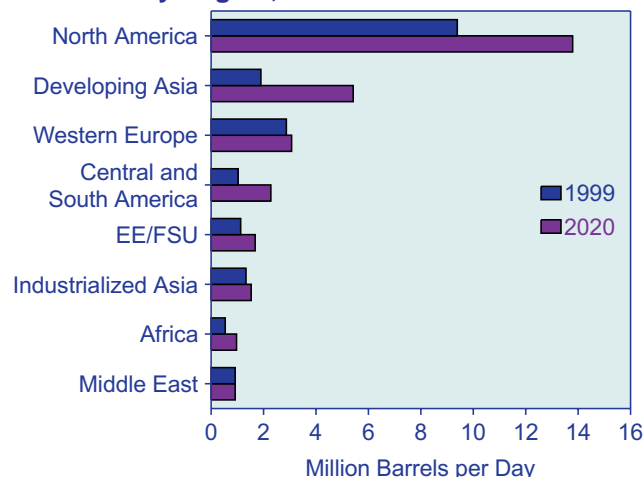
United States

High prices and tight markets for energy fuels over the past several years have moved energy security and energy policy issues back into prominence in the United

States. In May 2001, the Office of Transportation Technology (OTT) in the U.S. Department of Energy released a study on future highway energy use [23]. The study focused on advanced vehicle and fuel technologies as a means to lower oil consumption and reduce emissions without curtailing transportation service. Its purpose was to demonstrate that plausible alternatives exist, but that achieving them will require both continued technological advances and effective public policies. The study estimated that hybrid vehicles currently are 10 to 20 percent more expensive than conventional vehicles and that fuel cell vehicles are at least 20 percent more expensive.

The average fuel economy of new vehicles in the United States reached a 21-year low in model year 2001 at 20.4 miles per gallon, as a result of increased sales of sport utility vehicles, vans, and pickup trucks [24]. Higher vehicle fuel economy standards have been proposed as a means of reducing oil demand and imports [25], and a National Research Council study has suggested that automakers could significantly raise the fuel efficiency of passenger cars and light-duty trucks by 16 to 47 percent over the next 10 to 15 years [26]. Increasing corporate average fuel economy (CAFE) standards for light duty trucks, however, could result in a shift toward diesel fuel that would have implications for the refining industry. U.S. refiners normally target about a 2-to-1 ratio of gasoline to diesel production, and a significant decline could necessitate refinery modifications. In contrast to the United States, Europe typically exports gasoline and imports diesel fuel. If the United States shifts toward diesel fuel, the result may be excess gasoline production capacity and tight diesel markets [27]. In the absence of increased CAFE standards, EIA projects an increase of 0.3 percent per year in the fuel efficiency of the U.S. light-duty vehicle fleet [28].

Figure 83. World Motor Gasoline Demand by Region, 1999 and 2020



Sources: **1999:** Derived from Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **2020:** EIA, World Energy Projection System (2002).

The transportation sector is expected to contribute 89 percent of the projected increase in oil demand in the United States. One-fourth of the increase in world transportation energy use is expected to occur in the United States. Gasoline is expected to continue to dominate the sector, although its share is projected to decline slightly from 61 percent in 2000 to 58 percent in 2020.

Alternative fuels are not expected to penetrate the U.S. market to a large extent in the forecast period, despite some movement to alternative fuels. In California, 24 of the State's 43 largest transit agencies have opted for natural gas buses over diesel-powered engines with emissions reduction devices for ultra-low-sulfur diesel fuel. The natural gas buses are up to 15 percent more expensive but are far cleaner with respect to nitrogen oxide, air toxics, and soot [29]. CNG consumption in the United States is projected to grow by nearly 10 percent per year from 2000 to 2020.

Canada

Transportation energy use in Canada is projected to rise by 1.4 percent per year from 1999 to 2020. Canada has a transportation fuels market similar to that in the United States. Gasoline makes up 61 percent of Canada's transportation fuel demand, and its per capita consumption of transportation fuels is second only to that of the United States (12.4 and 17.8 barrels per person per year, respectively). Canada announced plans in February 2001 to harmonize certain fuel qualities with those of the United States in order to maintain product fungibility between the two countries. Sulfur levels in highway diesel fuel will be limited to 15 parts per million starting June 1, 2006, matching the U.S. requirement enacted in December 2000. Environment Canada is also developing future standards for off-road diesel and fuel oils and additional restrictions on gasoline [30].

Oil's share of transportation energy use in Canada is projected to remain at about 90 percent. The Government of Canada, however, is working with the alternative transportation fuels industry and major vehicle manufacturers to expand the use of fuel cells and fuels such as natural gas, ethanol, and electricity and is working to achieve new vehicle efficiency targets by 2010 [31]. In the 1990s, the average fuel efficiency of Canada's vehicle fleet improved despite the trend toward heavier and more powerful vehicles; however, with sales of minivans and sport utility vehicles expected to grow, efficiency gains are likely to be more challenging in the future [32].

The Canadian government launched a 12-month initiative in April 2001 to develop a federal strategy to respond to the major challenges that will face Canada's transportation sector over the next decade and beyond. The initiative will build on the work of the Canada

Transportation Review Act Panel and the Transportation Climate Change Table. The Transportation Review Act Panel made a number of wide-ranging recommendations related to enhancing competition, evaluating mergers, financing infrastructure, developing policies, and other areas. The Transportation Climate Change Table provided options for reducing greenhouse gas emissions from transportation, the largest source of greenhouse gas emissions in Canada [33].

The Canadian Pacific Railway is calling for transportation policy that promotes competition and allows natural market forces to prevail, pointing out that Canada is the only country in the world that enjoys the benefit of two competing national railway systems that are not supported by taxpayers [34].

Mexico

Transportation energy demand in Mexico is projected to grow at the fastest rate among the industrialized countries. By 2020, per capita consumption of transportation fuels is expected to approach the level in Japan. Road use is expected to dominate, accounting for 82 percent of transportation consumption in 2020. The number of vehicles per thousand people in Mexico currently stands at 25 percent of the level in the United States but is expected to jump to 48 percent of the U.S. level by 2020, with gasoline comprising about 58 percent of the increase in transportation fuel use.

Mexico is studying the possibility of replacing the gasoline blending component methyl tertiary butyl ether (MTBE) with ethanol made from sugar cane. The Mexican sugar industry, unable to meet the challenge of fructose imports, is facing a severe crisis of overproduction. Producing ethanol would help to eliminate the surplus, in addition to doing away with the controversial ether [35]. MTBE has been detected in groundwater samples in the United States, causing several States to restrict its use.

Considerable progress has been made in reducing air pollution in Mexico City. Over the past 10 years, ambient lead concentrations have been reduced by 98 percent, sulfur dioxide concentrations have fallen to acceptable levels, and few violations of the carbon monoxide standard remain. Serious problems still persist, however, with high concentrations of ozone and particulates. The transportation sector is the main source of air pollution in the Mexico City metropolitan area. Several measures were enacted in the 1990s to improve air quality, including tax policies to reduce the price differential between leaded and unleaded gasoline, the installation of vapor recovery systems at service stations, the introduction of reformulated gasoline and low-sulfur diesel fuel, upgraded emission standards for new vehicles, and inspection and maintenance

programs. The creation of an Environmental Trust Fund through a surcharge on gasoline in Mexico City is considered to be an important step in sustaining the progress that has been made [36].

Western Europe

Sustainable mobility was the impetus behind a White Paper developed by the European Commission that proposed some 60 measures aimed at bringing about substantial improvements in the quality and efficiency of transport in Europe. It also presented a strategy designed to gradually break the link between constant transport growth and economic growth, in order to reduce the pressure on the environment and prevent congestion while maintaining competitiveness. The proposals included a harmonization of fuel taxes across the countries, infrastructure development concentrating on filling in the missing links in trans-European networks, and improving safety and quality. Other measures were aimed at developing fair infrastructure charging, taking into account external costs and encouraging the use of the least polluting modes of transport. Another proposed objective was to shift the balance between modes of transport by 2010 by revitalizing the railways, promoting maritime and inland waterway transport, and linking up the different modes of transport [37]. Since 1980, the length of the European Union (EU) motorway network has increased by more than 70 percent, but railway lines and inland waterways have decreased by about 9 percent. Sixty percent of the international funding for the trans-European transport network has been targeted for rail, but actual investments are still biased toward highways [38].

Gasoline consumption in Western Europe in 1999 was at the same level as in 1990. Despite growth in car traffic, the static gasoline market resulted from the use of smaller, more efficient cars and the shift to diesel fuel. Consumers have been encouraged to purchase diesel-fueled cars through beneficial taxation policies, the development of efficient engines, and the perception that the fuel is more environmentally friendly [39]. These trends are projected to continue, with diesel fuel consumption estimated to rise by 0.7 million barrels per day from 1999 to 2020 (Figure 84) and gasoline by 0.2 million barrels per day.

The European Commission has also indicated that it plans to introduce a harmonized excise duty on diesel fuel across the EU that would be higher than the current average tax on diesel. The medium-range goal would be to tax gasoline and diesel similarly for all users. Exemptions for hydrogen and biofuels are expected to be included, not only for environmental benefits but also as a way to boost energy security [40].

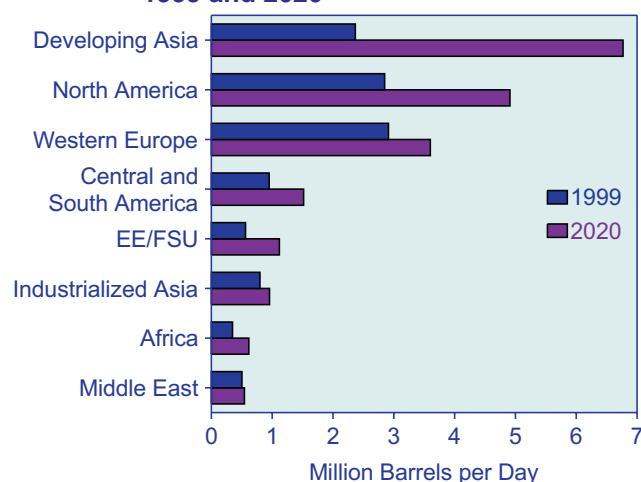
The September 11 attacks in the United States severely affected airline companies in Europe. British Airways

cut 7,000 jobs and reduced operations by 10 percent [41]. Swissair, which had been having financial difficulties for months, suspended operations on October 2 and resumed flights only after the Swiss government stepped in with a bailout package [42]. The European Commission approved compensation for losses that stemmed from the cancellation of flights to and from the United States for four days after September 11 but made it clear that no public subsidy would be permitted for any other reason [43]. Restructuring in the European airline industry is expected to result in only four or five international carriers plus an ensemble of regional carriers [44]. In the long term, however, strong growth in jet fuel consumption is expected. The increase in jet fuel consumption from 1999 to 2020 is projected to equal that of gasoline and diesel fuel for transport combined. By 2020, demand for air travel is expected to reach 19 percent of the region's transportation energy demand.

The United Kingdom is projected to contribute 22 percent of the increase in transportation energy use in Western Europe from 1999 to 2020. Consumption for air travel makes up a larger proportion of transportation demand in the United Kingdom than in continental European countries, and that share is projected to reach 27 percent by 2020. Despite the growth in air travel, London and the Southeast United Kingdom have added little runway capacity in the past 50 years. The Confederation of Business Industry has called for expansion of airport capacity, stating that it is essential for business and economic growth [45].

Despite the lower proportion of fuel consumption for road use in the United Kingdom as a whole, the people of London listed traffic congestion as the number one

Figure 84. Diesel Fuel Demand by Region, 1999 and 2020



Sources: **1999:** Derived from Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **2020:** EIA, World Energy Projection System (2002).

transportation issue that they wanted tackled. In addition to proposals to expand the capacity of the rail and subway lines, the Mayor of London has proposed congestion charging as a means to reduce traffic in the city [46].

Higher prices and a weak euro resulted in a small decrease in oil consumption in France in 2000. Diesel consumption, however, continues to increase due to a favorable tax regime. In 2000, 34.7 percent of privately owned cars in France had diesel motors, and a record 49 percent of new registrations were for diesel cars [47]. While the share of gasoline declines, diesel fuel is projected to continue to make up more than one-half of total transportation energy use in France.

Germany is the largest transportation market in Western Europe. Ultra-low-sulfur gasoline and diesel fuels (50 ppm) were introduced on November 1, 2001, without the price spikes and market disruptions sometimes associated with changes in product specifications. The fuels were brought into the market using tax incentives rather than mandates. Domestic refiners are producing most of the low-sulfur gasoline, but a significant portion is being imported [48]. Gasoline made up 50 percent of Germany's transportation fuel market in 1990, but its share is expected to fall to 43 percent by 2020. Strong growth is projected for jet fuel and diesel fuel consumption.

In an effort to improve air quality, Germany slashed the excise duty on CNG to a quarter of that on gasoline and diesel until 2009. That brings CNG down to 60 percent of the cost of traditional fuel on an energy equivalent basis. Excluding taxes, CNG is still 8 percent more expensive than natural gas delivered to households, which provides incentives to suppliers. Natural gas pumps are expected at 1,000 filling stations within 5 years. The program is aimed chiefly at commuters. CNG vehicles have a range of 109 to 124 miles, and the tank takes up about half a normal car's trunk space. The goal is to have 1 million vehicles running on natural gas by 2006, up from about 10,000 currently [49].

Italy ranks second to Argentina in numbers of natural gas vehicles with about 370,000 or about 1 percent of all vehicles. Italian motorists have been encouraged to switch from gasoline to CNG since the 1930s, when the wartime government was anxious to lessen reliance on imported oil [50]. At 612 vehicles per thousand people, Italy's per capita vehicle ownership is higher than that of Germany, France, or the United Kingdom. Road use fuel consumption currently amounts to 84 percent of Italy's transportation energy demand, ranking among the highest in Europe, and it is expected to remain relatively high at 80 percent in 2020.

Austria's OMV oil and gas group plans to install 20 new natural gas filling stations over the next 3 years, given a pending reduction of excise duty on CNG. An Austrian

network would enable motorists using CNG to drive from the northern part of Germany to southern Italy. The company estimates that 1 to 2 percent of Austria's vehicles could be running on CNG within 10 years [51].

Industrialized Asia

Transportation energy demand in industrialized Asia is projected to increase by 1.1 percent per year from 1999 to 2020, down from its 3.0-percent average annual growth rate from 1990 to 1999. Slower economic growth is expected for the region, and per capita vehicle ownership levels are already high, contributing to the expectation of slower growth in transportation fuel use.

Australia

The need to overcome large distances contributed to development of the transportation sector in Australia. About 567,302 miles of highways, 21,014 miles of rail, and more than 400 airports provide transportation infrastructure for the movement of goods and people [52]. Jet fuel's share of total transportation energy use is one of the highest among the countries in the forecast, and Australia has the second highest national per capita vehicle ownership rate after the United States.

Australia is expanding the number of CNG refueling sites, with the total expected to exceed 30 stations in the next 18 months. It is hoped that the increase in refueling sites will encourage motorists to consider the economic and environmental benefits of converting to CNG. With CNG sourced entirely within the country, prices are not affected by fluctuations in world crude oil prices or exchange rates [53].

Ansett Airlines became one of the victims of the post-September 11 slowdown in air travel. It ceased operations in September until the Australian government decided to underwrite tickets to get five airplanes back in operation. Qantas Airways picked up much of Ansett's 39-percent share of the Australian domestic air travel market, which helped to shield Qantas from the slowdown in international demand [54].

Japan

Despite the economic malaise of the past decade, per capita vehicle ownership in Japan grew at a higher rate than any other industrialized country in the forecast except Mexico. It was the used car market, however, that had the biggest boom. In contrast to 1990, when new car registrations were about 20 percent higher than used cars, used car registrations now exceed those for new cars by about 37 percent. Toyota and Honda are accelerating efforts to expand their used-car businesses in hopes of promoting sales of their new cars [55].

The market for mini-vehicles with lower costs and higher efficiencies is also growing in Japan. (Mini-vehicles are defined as vehicles with 0.66-liter engines or

smaller.) New mini-vehicle sales rose by 21.2 percent to a record 1.88 million units in 1999, the first gain in 4 years [56]. The use of smaller, more efficient vehicles and greater reliance on mass transit has helped to give Japan the lowest level of transportation energy consumption per unit of GDP among the countries in the forecast. In 1999, Japan's transportation energy intensity was 57 percent of the level in Western Europe and 31 percent of the level in the United States.

Public works projects have become a source of contention as the Japanese government steers between getting its runaway budget deficit under control and providing fiscal stimulus to keep the economy from sliding further into recession [57]. This was evident when three research councils associated with the ruling Liberal Democratic Party jointly adopted a resolution calling for full implementation of an expressway construction program, resisting Prime Minister Koizumi's plans to scale back Japan's expressway projects [58].

The Japanese Ministry of Land, Infrastructure and Transport is proposing to expand Tokyo's Haneda Airport rather than build a third airport in the greater Tokyo area [59]. Haneda's international flights had been limited to only those of Taiwan's China Airlines until February 2001, when Japan's three major airlines and two South Korean airlines were allowed to begin some international charter flights [60]. Tokyo's Narita Airport wanted to add a 1.6-mile runway to accommodate larger passenger airlines but was forced to scale back plans to only 1.4 miles as a result of disputes with farmers living next to the airport [61]. Until May 2001, Narita had only one runway, 2.5 miles in length [62].

Developing Asia

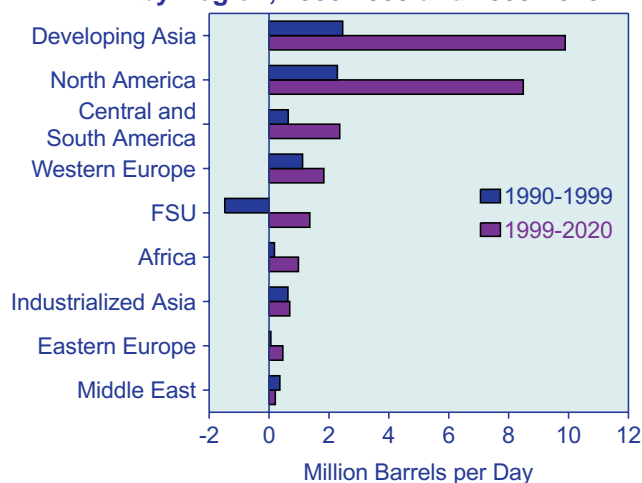
Developing Asia is expected to have the highest growth rate among the regions in the forecast, and transportation energy demand in the region is projected to exceed that in Western Europe by 2010, making it second in transportation fuel consumption after North America. Developing Asia is projected to account for 38 percent of the increase in world transportation energy demand from 1999 to 2020 (Figure 85), with an annual average growth rate of 4.9 percent. Jet fuel demand is expected to increase more than fourfold (Figure 86), and gasoline and diesel fuel consumption are projected to nearly triple.

China

The transportation sector was left out of China's economic plans for many years, and the resulting lack of infrastructure is a major bottleneck for the country's energy sector and overall economy. China has recently begun working on the development of roads, railways, and inland waterways. In 1999, the total length of operational freeways reached 7,208 miles, ranking third in the world behind the United States and Canada. China also plans to develop a high-speed railway network around the country.

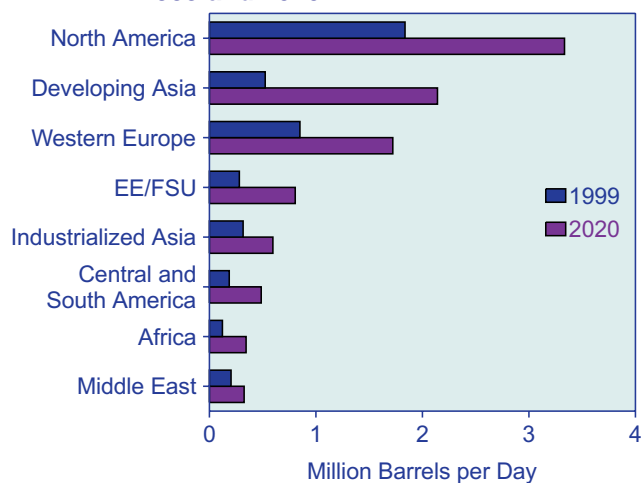
China's vehicle stock is dominated by heavy commercial vehicles, but passenger cars are expected to be the fastest growing component of in the forecast. Mass transit is expected to continue to dominate, however, and car density is expected to remain low in comparison with industrialized countries [63]. The number of vehicles per thousand people in China is projected to reach 52 in 2020

Figure 85. Changes in Transportation Energy Use by Region, 1980-1999 and 1999-2020



Sources: **1980-1999:** Derived from Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **1990-2020:** EIA, World Energy Projection System (2002).

Figure 86. Jet Fuel Demand by Region, 1999 and 2020



Sources: **1999:** Derived from Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **2020:** EIA, World Energy Projection System (2002).

from 12 in 1999. The projected strong growth in automobile sales reflect China's economic growth, the development of car financing, efforts to make car ownership easier, the launch of new models, and greater price competition [64].

Transportation energy demand in China is projected to grow by 6.4 percent per year from 1999 to 2020, increasing its share of world energy use for transportation from 4.1 percent in 1999 to 9.1 percent in 2020. China is expected to pass Japan by 2005 and become the world's second largest consumer of transportation fuels. The strongest growth is projected for gasoline, and gasoline consumption in China is expected to exceed that in Western Europe by 2020.

In 2000, China began to tie domestic petroleum product prices to international prices in Singapore. The prices were linked to the previous month's averages on Singapore's spot market, enabling wholesalers to estimate the price trends in advance and determine product volumes accordingly. This resulted in large demand swings for refiners and left them with unsold product. As a result, starting in October 2001, domestic gasoline and distillate prices were linked to Rotterdam and New York prices as well as Singapore. Linking the prices to Rotterdam and New York in addition to Singapore is expected to even out price volatility and limit the scope for manipulation [65].

The Air Transport Action Group predicts that China will overtake Japan as the dominant market for air travel in the Asia-Pacific region, projecting a rise from 70 million passengers annually in 1999 to 200 million by 2014 [66]. Pudong International Airport in Shanghai is planning to build a second runway and undergo further expansion that will make it the busiest airport in China and one of the busiest airports in the world by 2010 [67].

India

India's consumption of energy for transportation is projected to rise by 6.8 percent per year from 1999 to 2020, making it the third largest after the United States and China. On a per capita basis, however, India still would rank among the lowest in the world.

India has been advancing the use of CNG in an effort to reduce air pollution. Gujarat Gas Company, Ltd., is developing a compressed natural gas business in Gujarat. It has a pipeline network that feeds gas to users in the Surat, Ankleswar, and Bharuch areas and is already supplying CNG to about 800 vehicles in Surat city [68].

Delhi's compulsory transition of the city's entire public transport fleet to CNG revealed some of the difficulties that alternative fuels face. In July 1998, India's Supreme Court set a deadline of March 31, 2001, for the public

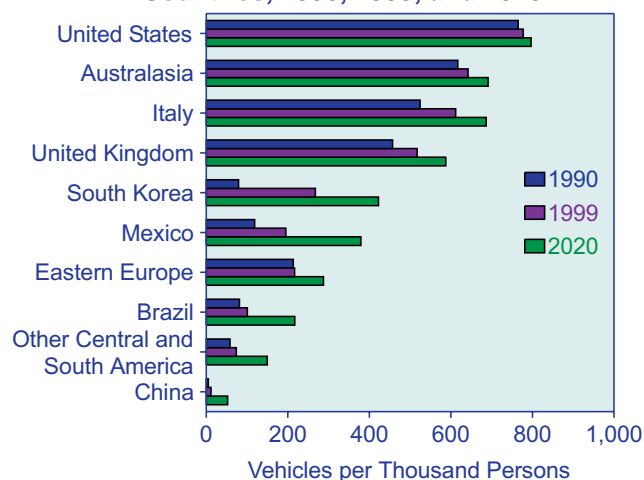
transport fleet in Delhi to be converted to CNG. A month before the deadline, however, only a fraction of the fleet had been converted, and the city had only three CNG bus filling stations [69]. The court extended the deadline to September 30, 2001, but restricted the number of diesel buses to the number of orders placed for new CNG buses or for conversions [70]. By October, only about one-third of the bus fleet was using CNG, and the court agreed to allow extra time. A new deadline is expected after the court reviews detailed plans and timetables from authorities and receives input from bus manufacturers, conversion agencies, and the gas supplier, Indraprastha Gas, Ltd. [71].

The Tata Energy Research Institute (TERI) called for the consideration of ultra-low-sulfur diesel as an alternative to CNG buses in Delhi, arguing that similar air pollution benefits could be obtained for a much cheaper price. TERI also pointed out some of the problems in the decisionmaking process, that the economics of the changeover and the practical feasibility of putting the infrastructure in place were not carefully considered, and that the decision was made without any trials being carried out under operating conditions [72]. The transition is being made, but the process has proven painful for those involved.

South Korea

Per capita vehicle ownership in South Korea increased by 14.5 percent per year from 1990 to 1999. The pace is expected to slow in the forecast period, but by 2020 the number of vehicles per thousand people in South Korea is projected to equal 53 percent of the level in the United States, as compared with 10 percent in 1990 (Figure 87). South Korea's automobile manufacturers have been

Figure 87. Motorization Levels in Selected Countries, 1990, 1999, and 2020



Sources: 1990 and 1999: Derived from Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). 2020: EIA, World Energy Projection System (2002).

struggling since the financial crisis of 1998. General Motors Corporation acquired Daewoo Motor Company in September 2001. Daewoo had been in court receivership since filing for bankruptcy in November 2000 after negotiations with Ford Motor Company broke down [73]. Hyundai/Kia is now the lone Korean-owned manufacturer [74].

Gasoline consumption makes up just 26 percent of the transportation fuel market in South Korea, primarily because its gasoline prices are among the highest in the world. Diesel fuel is less than half as expensive, and its consumption for transportation is 34 percent higher than that of gasoline [75]. Consumption of LPG for transportation use increased by nearly 25 percent per year in 1999 and 2000 and by another 13 percent in the first 3 months of 2001 [76]. That rapid growth is likely to slow, however, after a fourfold increase in the excise tax on LPG that started July 1, 2001. Additional tax increases are planned every 6 months for the next 5 years to bring the LPG price from 22 percent of the cost of gasoline to 65 percent. The government also plans to raise the excise tax on diesel fuel to bring its price to 80 percent of the gasoline price [77].

Jet fuel demand in South Korea is projected to more than triple over the forecast period. A new airport has been built in the greater Seoul area, Incheon International Airport, which can handle as many as 27 million passengers and 1.7 million tons of freight each year. South Korea is hoping that the new facility will help it compete with rival facilities in northeast Asia [78].

Other Developing Asia

The Thai cabinet approved a scheme that included builder tax incentives for four new ethanol plants using sugar cane and other crops. The government plans eventually to use ethanol in a 10-percent blend in all gasoline in an effort to reduce imports of oil and MTBE [79]. In July 2001, the government exempted non-petroleum portions of fuel from taxes, providing additional incentives for blending with ethanol and other alternative fuels. Higher oil prices and lower coconut and palm oil prices have led to renewed interest in biodiesel production. King Bhumibol Adulyadej holds a patent on palm-oil biodiesel, and a coconut-oil biodiesel process was patented in March 2001. The Petroleum Authority of Thailand (PTT) has been selling 3,000 to 4,000 liters (793 to 1,057 gallons) daily of 5 percent refined palm-oil biodiesel since July when the tax exemption began [80].

In spite of a growing vehicle population, Bangkok's air has become quantifiably cleaner over the past few years. Leaded gasoline has been banned since 1996, and all cars exported to and produced in Thailand are required to meet European emission standards. In 2001, 90 percent of new motorcycles sold in Bangkok were cleaner, more

fuel-efficient four-stroke models. In addition, open green space in Bangkok has more than doubled since 1993. While more progress is needed, Bangkok is slowly making improvements in air quality [81].

Jakarta, Indonesia, ranks as one of the most polluted cities in the world due in large part to automobile emissions. In 2000, atmospheric lead pollution was measured at 1.3 micrograms per cubic meter, above the World Health Organization limit of 0.5 to 1.0 micrograms per cubic meter. Controlling air pollution has been difficult because the economic slowdown has not hindered the growth in the number of vehicles, which has continued at 15 percent per year, but has made it more difficult for Pertamina, the national oil company, to secure loans to build catalytic reformers to provide the high-octane blending components needed to produce unleaded gasoline [82]. Indonesia is still planning to phase out leaded gasoline by 2003. Pertamina is continuing to upgrade its refineries to meet the fuel standards but expects that imports of unleaded gasoline may be needed to meet demand [83].

Air quality has deteriorated significantly in Hong Kong in recent years. Vehicles are the primary cause of street-level pollution, producing smoke, particulates, and chemicals in quantities that regularly exceed health standards. In May 2001, participants in a Cleaner Vehicles and Fuels Workshop gathered ideas and developed action plans for reducing vehicle emissions. The group recommended that Hong Kong establish an Energy Commission to develop a clear, coordinated energy policy. The Commission would develop long-term policies to remove barriers to the introduction of cleaner vehicles and fuels, adopt performance-based incentives to promote the cleanest vehicles and fuels infrastructure, develop an integrated education and training strategy, and promote research and development. The ultimate goal is to achieve zero emissions from transportation, probably by means of hydrogen-powered fuel cell vehicles [84].

Central and South America

Central and South America is one of the most urbanized regions of the developing world, with approximately 80 percent of its population residing in metropolitan areas and more than 55 metropolitan areas of 1 million inhabitants or more. The process of urbanization has occurred fairly rapidly and has accelerated dramatically in the past 30 years. The urban transportation sector is commonly regarded as one of the main culprits behind the high levels of urban air pollution in the region [85].

Congestion is also a major problem. Per capita vehicle ownership in Central and South America is much higher than in other developing regions, although it remains considerably lower than in the industrialized countries.

The number of vehicles per thousand people in Central and South America is projected to increase to 215 by 2020. Some cities have begun a strategy of deemphasizing cars and providing public transport instead. Curitiba, Brazil, built a system of dedicated busways and zoned for higher density development along those thoroughfares. The city now enjoys better air quality and more parks for its 2.5 million people. Car-free days are also being used to promote public transportation and reduce dependence on cars [86].

Most of the countries in Central and South America have phased lead out of gasoline in the past several years. When Venezuela completes its lead phasedown program, nearly all gasoline in the region will be lead free. Venezuela has targeted 2015 for lead phaseout, but discussions are under way to move up the date. Venezuela will likely accomplish the phaseout by converting its large leaded premium pool into unleaded regular gasoline with minimal octane loss [87].

Brazil

Brazil has nearly 1.2 million miles of roads—more than twice as many as Australia, Canada, or Russia—but less than 10 percent are paved [88] and road conditions in the rural sections are often poor [89]. The road portion of transportation energy use in Brazil is projected to decline slightly to 84 percent by 2020, and per capita vehicle ownership is expected to more than double to 217 vehicles per thousand people.

Congestion and air pollution are big problems in Brazil's cities. In 1999, 90 percent of Sao Paulo's smog resulted from motor vehicle emissions. Sao Paulo's pollution levels are fueled by poor infrastructure design, gasoline prices that are among the lowest in the world, and inefficient automobiles. The local government instituted a pollution control program in 1999 requiring that motorists leave their cars home one day a week. An orbital motorway, additional metro lines, and improvements to the rail system are also planned to improve environmental conditions [90].

Gasoline in Brazil consists of about 20 percent ethanol made from sugar cane. The Brazilian National Alcohol Program started in the 1970s as an alternative to oil and to promote self-sufficiency. The ethanol market is regulated to keep the price competitive with gasoline [91]. Gasoline prices are controlled at the refinery but not at the pump. Refinery prices are adjusted every 3 months, taking into account international oil prices and the value of the Brazilian real in relation to the U.S. dollar [92]. The Petrobras monopoly on refining and distribution of petroleum products came to an end in 1998, and since then other companies have sought to expand into Brazil's market. Petroleos de Venezuela (PDV) has plans

to open a number of gasoline stations in Northeastern Brazil starting in the fourth quarter of 2001 [93].

Argentina

Argentina's recession continued, with the economic situation deteriorating sharply in the summer of 2001. The International Monetary Fund (IMF) provided additional monetary assistance in September 2001, but most analysts do not think it will be sufficient to prevent further financial difficulties [94].

Argentina has an extensive transportation network, much of which has been privatized over the past decade. Maintaining and upgrading the highway system is a challenge in a country that stretches 2,485 miles from north to south. Argentina has 133,592 miles of highways, of which 29 percent are paved [95]. An estimated 87 percent of passenger and 85 percent of domestic freight traffic is carried by road. The most highly traveled sections of more than 30 national highways have become privately operated toll roads. Traffic managers have stressed that improved road conditions on those highways reduce vehicle maintenance costs and travel time, more than making up for the fees that drivers have to pay. Moreover, the government has been able to apply road taxes to repair secondary roads, pave dirt roads, and construct new roads [96].

Some 8 million cars and a large fleet of buses operate in the city of Buenos Aires each day, creating serious health problems [97]. A workshop sponsored by the World Bank Clean Air Initiative identified improved inspection and maintenance systems and the planning and development of a cycle lane system as two important projects to help reduce emissions and congestion [98]. In addition, Argentina is planning to reduce sulfur levels in gasoline and diesel fuel to 50 ppm by 2006 [99]. Tax incentives for biodiesel have been announced in an effort to help farmers as well as reduce emissions. The incentives, which extend to excise, income, and property taxes, could allow production of biodiesel at sales prices well below that of regular diesel fuel [100]. Argentina also has 687,000 natural gas vehicles, more than any other country in the world [101].

In the early 1970s, Argentina could boast that all its cities with a population of 10,000 or more (with the exception of Ushuaia in Tierra del Fuego) were served by rail; however, government ownership led to management decisions that were often based on politics, government priorities, and expediency. Investment and research and development were deemphasized, and by the late 1980s huge operating subsidies were required to keep the system running at even a marginal level. Since 1992, all but one of Argentina's railways have been privatized. Since privatization, the passenger and freight traffic have

risen and service has improved. The railroad industry is also trying to improve its relationship with ports to persuade traders that rails can serve them as well as trucks [102].

Waterways are an important part of Argentina's transportation sector. Nearly 90 percent of the country's foreign trade passes by water through its sea and river ports. Argentina has 2,175 miles of navigable waterways. Since privatization, investment has gone into increasing port capacity and improving operations. The work force has been reduced by 75 percent, management has been restructured, and operations have been streamlined. Argentina's move to revamp its marine terminals and waterways should bolster the country's increasingly important waterborne trade [103].

Aerolineas Argentinas was grounded for 5 months in 2001 after declaring bankruptcy protection when two of the seven unions representing its employees refused to go along with a restructuring plan that would have slashed wages and benefits in return for guaranteed job continuity. Flights resumed in November under new ownership [104].

Middle East

Gasoline makes up a larger share of the transportation fuel market in the Middle East than in other developing regions. As a result of slower growth in motorization rates, transportation demand in the region is projected to increase by 0.6 percent per year from 1999 to 2020. Jet fuel is expected to show the strongest growth as air travel expands in the region.

The large increase in traffic that has ensued from Saudi Arabia's economic development made it necessary to upgrade several of the nation's inter-city roads to multi-lane expressways. Traffic congestion in the cities has also resulted in the development of ring roads around city centers, as well as overpasses and underpasses to keep traffic flowing [105]. Air pollution in Saudi cities is the lowest in the Middle East and should continue to improve with the introduction of unleaded gasoline in January 2001. The switch to unleaded gasoline will result in the need for an estimated 3 million catalytic converters in order to reduce pollution from vehicle exhaust [106].

In 1945, U.S. President Roosevelt presented Saudi King Abdul Aziz with a DC-3 Dakota airplane. The King quickly realized the contribution that air travel could make to the development of the Kingdom and promptly ordered two more planes. Saudi Arabia now has three international airports and 22 regional and local airports, linking together all parts of the country [107].

Dubai International Airport in the United Arab Emirates is the fastest growing airport in the region. It handled 6.8

million passengers in the first half of 2001, up by 14 percent from the same period in the previous year. Freight traffic increased by 8 percent [108]. A \$2.5 billion expansion program was announced to add another terminal and two concourses. Completion is planned for 2006 [109].

Africa

Maintaining the road infrastructure has been a big challenge for much of Africa. At the end of the 1980s, Sub-Saharan Africa had nearly 1.2 million miles of roads worth about \$170 billion, but nearly one-third of that investment has been lost through lack of maintenance. A Road Maintenance Initiative (RMI) was launched, bringing the roads into the marketplace, setting fees for use, and managing them like any business enterprise. Although the pace and impact of reform have been slower than expected, several countries have shown substantial increases in the proportion of main roads designated as "good." Conditions on rural and feeder roads have not improved, however, and the Sub-Saharan Africa Transport Policy Program is accessing obstacles to continued improvements and ways to overcome them [110].

Former Soviet Union

Transportation energy demand declined by 7.3 percent per year from 1990 to 1999 in the former Soviet Union (FSU) as a result of the turmoil that accompanied the end of the Soviet era. Trucks used to dominate the traffic on Russian city streets, but private car ownership grew rapidly in the 1990s [111]. Road use energy demand in the FSU is projected to increase by 3.3 percent per year from 1999 to 2020 and jet fuel demand by 4.8 percent per year. By 2020, transportation energy demand in the FSU is expected to be at nearly the same level as in 1990.

Infrastructure development remains a serious concern in Russia. In the 1990s, roads, bridges, and other infrastructure fell into an advanced state of decay, and investment was inadequate for the needed repairs [112]. As fast as the Russian economy declined, investment declined even faster. A combination of low domestic savings, limited foreign investment, and government deficits resulted in an investment crisis that hindered infrastructure development [113]. Over the past several years, however, Russia has shown strong economic growth. Higher oil prices, exchange rate depreciation, and moderating inflation have contributed to a renewal of economic growth and an improved investment climate [114].

Eastern Europe

Transportation energy demand in Eastern Europe fell as a result of the economic turmoil that occurred after the collapse of the Soviet Union, but from 1990 to 1999 it grew at an average annual rate of 1.1 percent. The

transportation infrastructure in Eastern Europe shows the effects of 40 years of central planning and lack of investment. The density of the national public road networks and their quality are generally lagging far behind road network standards of EU countries. Many roads are in poor repair because they were not made to handle the current high volumes of traffic and the weight of modern trucks [115]. Travelers and goods used to move mainly by train but the importance of railways is decreasing and the future of many rural lines is uncertain. The frequency of service has declined and fares have increased [116]. Fuel quality also lags behind that in Western Europe, but countries in Eastern Europe are working hard to improve fuel quality to harmonize with EU fuel standards. Gasoline's share of the market is much higher in Eastern Europe than in Western Europe.

Poland

Poland is using tax incentives to encourage consumption of unleaded gasoline and low-sulfur diesel fuel. More than 80 percent of the diesel fuel currently used is estimated to contain less than 500 ppm sulfur, and 25 percent contains less than 50 ppm sulfur. The excise tax on 500 ppm sulfur fuel is 5 percent less than the tax on diesel fuel with 2,000 ppm, and diesel fuel with a sulfur content of 50 ppm has an excise tax that is 1.5 percent less than that on 500 ppm fuel. The excise tax on unleaded gasoline is 10 percent less than on leaded fuel, but the market penetration of unleaded gasoline has been slower because cars in the country average 10 years old, and only 27 percent are equipped with catalytic converters. In 2000, unleaded gasoline made up 20 percent of total gasoline sales [117].

The Polish government is also proposing to commercialize, restructure, and partially privatize the Polish State Railways (PKP) over the period 2001-2003. The reform initiative aims to encourage the development of rail transport services that meet the needs of a market economy, reduce the burden on the state imposed by PKP's heavy losses, and help to prepare the transport system for Poland's entry into the EU. The World Bank approved a loan for the project, which includes severance payments and redeployment services for displaced workers [118].

Romania

Romania's transportation infrastructure reflects many years of poor investment. Most roads are in poor condition, and only 25 percent of the road network is modernized. Road density with regard to both population and land area is the lowest among all central and east European countries [119]. Car ownership is increasing rapidly, but most of the cars on the road in Romania are old and poorly maintained, running on gasoline that has the highest lead content in Eastern Europe [120]. Vehicle ownership in the country increased by 79 percent from

1990 to 1996, and more than 80 percent of the vehicle fleet is gasoline powered. All new vehicles, imported and domestically produced, are now required to have catalytic converters. Romania is planning a complete phaseout of leaded gasoline by 2003 [121].

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